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(54) Title: METHOD AND APPARATUS FOR BAND-ADAPTIVE DEMODULATION

(57) Abstract

In a multi-band, digital communication system such as a dual-band digital cellular telephone system, baseband signal processing is accomplished by selecting, from amongst a number of baseband signal processing parameter sets, a best, most appropriate baseband signal processing parameter set, as a function of the frequency band and the received communication signal.
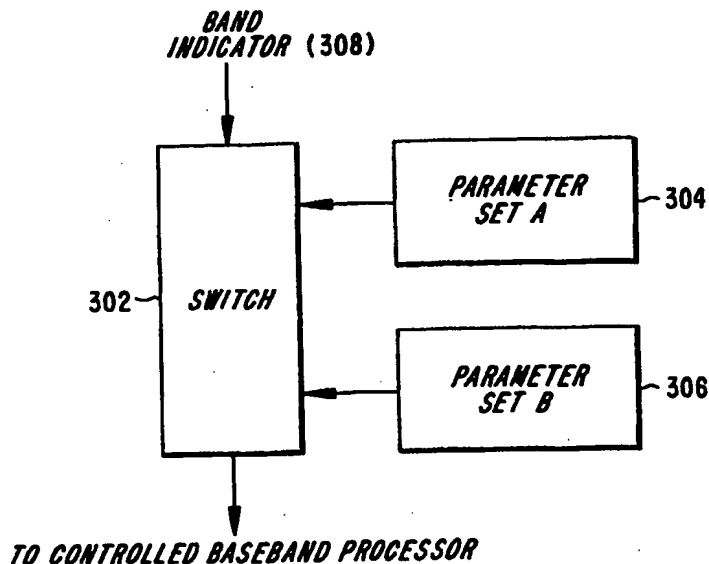
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METHOD AND APPARATUS FOR BAND-ADAPTIVE DEMODULATION

BACKGROUND

The present invention relates to the
5   processing of signals in a communication system.   More
particularly, the present invention relates to
adaptively demodulating a baseband signal in a
communication system as a function of the frequency band
in which the corresponding modulated signal was
10   transmitted.

The demand for wireless communication
services has been expanding at an extraordinary rate.
To accommodate this demand, the radio spectrum available
for wireless communication has increased.   For example,
15   wireless communication systems, such as cellular
telephone systems, now use a mixture of cellular and PCS
frequency bands.   Thus, as customers travel across the
country and receive service from different cellular
providers, the cellular customers now, more than ever,
20   require mobile phones that are capable of dual-band
operation to assure seamless phone service.

In addition, various modulation methods and
multiple access techniques have been employed to further
satisfy the high demand for wireless services.
25   Frequency division multiple access, or FDMA, is, of
course, the traditional method.   Here, the frequency
spectrum is divided into a number of radio channels,
wherein each channel corresponds to a different carrier
frequency.   Time division multiple access, or TDMA, is

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another method in which each carrier frequency or frequency channel in an FDMA system is further divided into time slots, each of which are assigned to a different user. Therefore, each frequency channel can accommodate multiple users. As will be recognized by one of ordinary skill in the art, TDMA and FDMA are employed in the D-AMPS, PDC, and GSM digital cellular systems. If the radio channel is wide enough, multiple users can use the same channel using spread spectrum techniques and code division multiple access or CDMA. IS-95 and J-STD-008 are examples of CDMA standards.

In a digital communication system, information such as cellular speech, e-mail and internet data is represented by a series of binary information symbols. These binary information symbols are then encoded and modulated so that they can be transferred from a sending unit to a receiving unit over a transmission medium, such as a wire, the air, or magnetic tape. For example, in a digital cellular phone system, the bits representing cellular speech are modulated and the resulting waveform is then transmitted from a base station to a cellular mobile phone unit. In order for the cellular customer to hear the speech, the mobile phone must employ a receiver capable of receiving and demodulating the waveform, and ultimately capable of recovering the sequence of binary information symbols to reproduce the speech.

To accomplish this, a digital receiver comprises, among other things, a radio signal processor.

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The radio signal processor is tuned to the frequency band and carrier frequency of the transmitted signal. This allows the receiver to pick-up the transmitted signal. The radio signal processor then amplifies,

5   mixes, and filters the transmitted signal down to baseband. While baseband typically refers to zero intermediate frequency, it is used herein to refer to a fixed reference intermediate frequency.

        The transmission medium, however, can

10   introduce interference and other phenomena that may distort the transmitted signal. For example, the transmission medium may introduce intersymbol interference, multipath effects or co-channel interference. In addition, a frequency error at the

15   receiver may cause the baseband waveform to rotate, thereby affecting the received signal's in-phase (I) and quadrature (Q) components. These effects are not generally removed from the transmitted signal by the radio signal processor. Therefore, in order to recover

20   the desired binary information symbols from the baseband signal, a receiver typically employs a baseband processor.

        In dealing with signal interference and distortion, the baseband processor may, in turn, employ

25   an equalizer. An equalizer is a specialized filter that tracks various channel characteristics, for example, the extent to which the waveform is distorted by the transmission medium. In general, the equalizer tracks channel characteristics by periodically obtaining a

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channel tap. This is accomplished by generating
expected received values (e.g., using known or detected
symbols). The expected received values are compared to
the actual received values, and the difference between
5   what was actually received and what was expected
reflects the channel characteristic being tracked. The
equalizer can then use this information to adjust the
channel tap estimates to compensate for the interference
and/or distortion introduced by the transmission medium.
10   The adaptation rate or the rate at which the
equalizer obtains a channel tap is often referred to as
the channel tracking step size. The channel tracking
step size depends upon how fast the channel is changing.
This, in turn, depends upon, among other things, the
15   corresponding frequency band and/or the carrier
frequency of the transmitted signal. For example, the
higher the frequency band or carrier frequency, the
faster the channel characteristics tend to change.
However, the radio signal processor removes the carrier
20   frequency, hence, this information is not available to
help the baseband processor decide how to properly set
the adaptation rate. Consequently, baseband processors
are traditionally designed to set the adaptation rate in
accordance with worst possible case conditions (e.g.,
25   the highest frequency band and/or the highest carrier
frequency).

          When the worst case conditions are not in
fact present, the traditional method for setting the
adaptation rate based upon a worst case scenario results

in overuse of baseband signal processing or poor tracking performance. Overuse of baseband processing tends to be very time consuming, it results in less accurate binary information symbol detection, and it can rapidly drain the receiving unit's power source (e.g., a battery).

Other solutions have been proposed. For example, U.S. Patent 5,230,007 (Baum et al.) proposes to adapt the channel tracking step size in response to the performance of the channel tracker itself. Such an approach requires added complexity in estimating performance for different tracking step sizes and determining which tracker is performing best. Because performance estimation is not perfect, the best tracking step size is not always utilized. Alternatively, U.S. Patent 5,268,930 (Sendyk et al.) proposes to estimate the speed of the mobile phone to determine channel tracking step size. Again, there is added complexity, because of the need to estimate the speed of the vehicle in which the phone is being transported. Also, inaccurate vehicle speed estimations will result in performance loss.

Therefore, in a digital communication system that employs a relatively large dynamic frequency range, such as a dual-band cellular telephone system, there is a need to improve the efficiency of the receiver. In particular, there is a need to improve the baseband processing function of the receiver, such that the baseband processor can more efficiently compensate for

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interference and distortion introduced by the
transmission medium, more accurately recover the binary
information symbols, and reproduce a high speech
quality, without placing an excessive drain on the power
5   source of the unit.

SUMMARY

Accordingly, it is an objective of the
present invention to provide a receiver that has the
10   ability to process baseband signals more efficiently and
effectively.

It is another objective of the present
invention to provide a multiple or dual-band receiver
that possesses a baseband processor capable of
15   adaptively processing a baseband signal without overuse
of baseband processing, accurately detecting the
communication information, and preventing rapid drain on
a power source.

In accordance with one aspect of the present
20   invention, the foregoing and other objects are achieved
by a system and/or a method that involves generating a
baseband signal from a received radio frequency signal;
selecting a set of processing parameters based on the
frequency band of the radio frequency signal; and
25   adaptively processing the baseband signal using the
selected set of processing parameters.

In accordance with another aspect of the
present invention, the foregoing and other objects are
achieved by a radio receiver and/or a method for

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receiving radio signals wherein a baseband signal is
produced from a received radio frequency signal and a
control signal is generated as a function of the
received radio frequency signal's frequency band. The

5   receiver and/or method also involves a baseband
processor for receiving and processing the baseband
signal, and a baseband processor control unit for
adaptively controlling the baseband processor as a
function of the control signal.

10   In accordance with another aspect of the
present invention, the foregoing and other objects are
achieved by a system and/or method that involves
receiving and converting a communication signal into a
baseband signal; providing frequency band information

15   corresponding to the communication signal; extracting
digital information from the baseband signal; and
adaptively controlling the baseband processor as a
function of the frequency band information.

20   **BRIEF DESCRIPTION OF THE DRAWINGS**
                The objects and advantages of the invention
will be understood by reading the following detailed
description in conjunction with the drawings in which:
                FIG. 1 is a diagram of a digital

25   communication system in accordance with the prior art;
                FIG. 2 is a diagram of a digital
communication system in accordance with one aspect of
the present invention;

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FIG. 3 is a diagram of an exemplary band-adaptive baseband controller;

FIG. 4 is a diagram of a baseband processor containing a channel tracker and a coherent detector; and

FIG. 5 is a flowchart depicting an exemplary method in accordance with the present invention.

DETAILED DESCRIPTION

The various features of the invention will now be described with respect to the figures, in which like parts are identified with the same reference characters.

A typical digital communication system 100 is shown in FIG. 1. In such a system, digital symbols are provided to a transmitter 102. The transmitter 102 then applies modulation to the digital symbols, maps them to a representation that is appropriate for a transmission medium 104 (e.g., air), and transmits the modulated signal over the transmission medium 104 to a receiver 105.

The receiver 105 comprises a radio processor 106, a control unit 108, and a baseband signal processor 110. The control unit 108 provides the radio processor 106 with information regarding the signal band (i.e., frequency band information), and possibly carrier frequency information, corresponding to the transmitted signal. The radio processor 106 then filters, amplifies, and mixes the received signal down to

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baseband or alternatively, down to an intermediate
frequency (IF) band. The baseband processor 110
receives the baseband or IF signal from the radio
processor 106, processes the baseband or IF signal in
5   accordance with one or more parameter sets, and produces
estimates of the digital symbol values. As one skilled
in the art will recognize, the baseband processor 110
may also provide soft estimates of the digital symbol
values as well as reliability information. The
10   estimated digital symbol values are then converted into,
for example, speech, text or images.

As stated, the baseband processor 110
processes the baseband or IF signal, in accordance with
a set of signal processing parameters. For example, the
15   parameter set may define the rate at which a channel
tracker within the baseband processor 110 will obtain
channel taps. The information derived from the channel
taps is then used to adjust the baseband signal to
compensate for interference and distortion introduced by
20   the transmission medium 104. However, the selection of
one set of parameter values over another set of
parameter values may depend upon the rate at which the
channel characteristics are changing. This, in turn,
will depend upon several factors including the frequency
25   band and/or carrier frequency of the transmitted signal.
Since the baseband processor 110 does not possess
information relating to the frequency band or carrier
frequency of the transmitted signal, the baseband
processor 110 cannot select an appropriate set of

parameter values. Instead, the baseband processor 110

is designed with a fixed set of parameter values which

assume a worst case condition (i.e., the highest

possible frequency band or carrier frequency). As

5   stated above, assuming a worst case condition, when the

worst case condition is not in fact present, results in

an inefficient and often inaccurate baseband processing

function.

          In contrast, a digital communication system

10   200, in accordance with a preferred embodiment of the

present invention, is shown in FIG. 2, where like

elements with FIG. 1 correspond to each other. A

receiver 205, like receiver 105, comprises the radio

processor 106. In addition, the receiver 205 comprises

15   a control unit 208, a band-adaptive baseband controller

209, and a controlled baseband signal processor 210.

          Unlike in the receiver 105, the band-

adaptive baseband controller 209 receives information

from the control unit 208 relating to the frequency

20   band, and possibly the carrier frequency, corresponding

to the transmitted signal. In general, frequency band

can refer to a collection of radio channels or one radio

channel. The band-adaptive baseband controller 209

utilizes this frequency band information to control the

25   baseband processing function performed by the controlled

baseband processor 210. For example, the band-adaptive

baseband controller 209 can select from amongst a number

of baseband signal processing methods (or sets of

baseband processing parameters), a best, most

appropriate signal processing method given the frequency
band or carrier frequency information provided by the
control unit 208.

An exemplary embodiment of the band-adaptive

5   baseband controller 209 is illustrated in FIG. 3.
According to this exemplary embodiment, the band-
adaptive baseband controller 209 comprises a switch 302
and at least two baseband signal processing parameter
sets 304 and 306. The switch 302, which one of skill in

10   the art will recognize, may be implemented in hardware
and/or software, is operatively connected to a frequency
band indicator signal 308. If an application involves a
cellular telephone communication system, the frequency
band indicator signal 308 may identify that the

15   frequency band is the lower frequency cellular band or,
alternatively, the higher frequency PCS band. The
switch 302 then provides the most appropriate baseband
signal processing parameter set 304 or 306 to the
controlled baseband processor 210, which in turn

20   receives and utilizes the most appropriate parameter set
to process the baseband signal. For example, each of
the at least two baseband signal processing parameter
sets 304 and 306 may contain parameters for establishing
a different channel tracking step size. Alternatively,

25   each of the at least two baseband signal processing
parameter sets 304 and 306 may contain different loop
filter coefficients for an automatic frequency
correction (AFC) unit.

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An exemplary embodiment of the controlled baseband processor 210 is illustrated in FIG. 4. In FIG. 4, the controlled baseband processor 210 is shown to include a channel tracker 407 and a coherent detector

5   408. The parameter values associated with the most appropriate parameter set, given the frequency band or carrier frequency information provided by the band-adaptive baseband controller 209, are made available to the channel tracker 407. As stated, the parameter set

10   may include parameters that specifically control the channel tracking step size. The channel tracker 407 utilizes the parameter values provided by the band-adaptive controller 209, the baseband signal provided by the radio processor 106, and detected digital symbol

15   values from the coherent detector 408 to track the channel. Upon processing the baseband signal, in accordance with the most appropriate parameter set, the coherent detector 408 can more accurately detect the digital symbols. One skilled in the art will also

20   readily understand that the coherent detector 408 may include an equalizer, the function of which was described above. More specifically, in a TDMA system, the coherent detector 408 could be a maximum likelihood sequence estimation (MLSE) equalizer. In a CDMA system,

25   the coherent detector could be a Rake receiver. In either case, if known symbol values are used to detect the channel (e.g., pilot channel or pilot symbols), then the output of the coherent detector 408 need not be provided to the channel tracker 407.

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Although the above-identified embodiment is focused on a channel tracking application, the present invention is not limited to baseline processing involving channel tracking. In yet another exemplary

5 embodiment, the selected parameter set provided by the band-adaptive baseband controller 209 can be used to determine how complex the demodulation of the baseband signal has to be. For example, while one frequency band may require the use of per-survivor-processing, another

10 band may not, where per-survivor-processing involves utilizing multiple channel estimates each corresponding to different possible symbol sequences, as is well known in the art. In yet another exemplary embodiment, the selected parameter set can be used to determine how fast

15 to track equalizer filter coefficients in, for example, transversal or decision feedback equalizers. In general, the selected parameters may include, control signals for selecting various baseband processing functions.

20 In still another exemplary embodiment, the selected parameter set provided by the band-adaptive baseband controller 209 can be used to control the process by which the baseband processor 210 updates the estimation of a particular channel characteristic. For

25 example, the estimation of a particular channel characteristic X might be updated in accordance with the following relationship:

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$$X_{present} = X_{previous} + \lambda \, X_{update}$$

(1)

where λ represents a weighting function. As stated
above, the PCS band is a higher frequency band than the
cellular band. It was also stated above that channel
characteristics tend to change more rapidly with respect
to higher frequencies. Therefore, in the above-
identified relationship, it may be more appropriate to
apply a higher weighting factor λ to $X_{previous}$ if the
corresponding frequency band is the PCS band. In
contrast, it might be more appropriate to apply a lower
weighting factor λ to $X_{previous}$ if the corresponding
frequency band is the cellular band. In accordance with
this exemplary embodiment of the present invention, the
particular value of the weighting factor λ could be
selected by the band-adaptive baseband controller 209,
as a function of the given frequency band, and
subsequently supplied to the controlled baseband
controller 210 for use in processing the baseband
signal.

A flowchart depicting a general technique
for accomplishing any of the above-identified
embodiments is shown in FIG. 5. The technique begins
when a modulated waveform is received from the
transmitter (step 505). A signal is then generated
indicating the frequency band, and possibly the carrier
frequency, associated with the transmitted signal (step
510). The transmitted signal is then filtered,

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amplified and mixed down to baseband, or alternatively
to an IF band (step 515). A test is performed to
determine the corresponding frequency band, in
accordance with the band information provided by the
5   indicator signal described above. If the corresponding
frequency band is high, indicating for example, the PCS
band, in accordance with the "HIGH" branch out of
decision block 520, then a first set of baseband signal
processing parameters will be selected (step 525).
10   However, if the corresponding frequency band is low,
indicating for example, the cellular band, in accordance
with the "LOW" branch out of decision block 520, then a
second set of baseband signal processing parameters will
be selected (step 530). The baseband signal, or the IF
15   signal, is then processed in order to extract the
digital symbol information in accordance with the
selected parameter set (step 535).

        The invention has been described with
reference to several exemplary embodiments. However, it
20   will be readily apparent to those skilled in the art
that it is possible to embody the invention in specific
forms other than those of the preferred embodiment
described above. This may be done without departing
from the spirit of the invention. The preferred
25   embodiment is merely illustrative and should not be
considered restrictive in any way. For example, the
invention is described primarily in the context of a
radio communication system, wherein that modulated
signal is transmitted over the air; however, the

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invention is not limited to such a system. It also is applicable to wireline communication systems and magnetic storage systems. Thus, the scope of the invention is given by the appended claims, rather than the preceding description, and all variations and equivalents which fall within the range of the claims are intended to be embraced therein.

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WHAT IS CLAIMED IS:

1.   A baseband signal processor comprising:
        radio signal processing means for generating
a baseband communication signal from a received radio
frequency signal;
        baseband processor control means for
selecting a set of processing parameters based on a
frequency band corresponding to the received radio
frequency signal; and
        baseband processor means for adaptively
processing the baseband communication signal using the
selected set of processing parameters.

2.   The baseband signal processor of claim 1,
wherein the selected set of processing parameters
includes channel tracking parameters.

3.   The baseband signal processor of claim 2,
wherein the channel tracking parameters include a
parameter value defining channel tracking step size.

4.   The baseband signal processor of claim 1,
wherein the selected set of processing parameters
includes automatic frequency control parameters.

5.   The baseband signal processor of claim 4,
wherein the automatic frequency control parameters

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include parameter values defining loop filter
coefficients.

6.   A radio receiver comprising:

radio signal receiving means for producing a
baseband signal from a received radio frequency signal;

frequency indicator means for generating a
control signal as a function of a frequency band
corresponding to the received radio frequency signal;

baseband processor for receiving and
processing the baseband signal; and

baseband processor control unit for
adaptively controlling the baseband processor as a
function of the control signal.

7.   The receiver in claim 6, wherein the
baseband processor control unit comprises:

a switch for selecting a set of baseband
processing parameters as a function of the control
signal.

8.   The receiver in claim 7, wherein the
baseband processor processes the baseband signal in
accordance with the selected set of baseband processing
parameters.

9.   The receiver in claim 8, wherein the
selected set of baseband processing parameters includes
channel tracking parameters.

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10.   The receiver in claim 8, wherein the
selected set of baseband processing parameters includes
automatic frequency control parameters.

5   11.   A digital communication system comprising:
                  a radio processor for receiving and
converting a communication signal into a baseband
signal;
                  a receiver control unit for providing
10   frequency band information corresponding to the
communication signal;
                  a baseband processor for extracting digital
information from the baseband signal; and
                  a baseband processor control unit for
15   adaptively controlling the baseband processor as a
function of the frequency band information.

         12.   The system of claim 11, wherein the baseband
processor control unit comprises:
20   ————— ———— —a switch for selecting a set of baseband
processing parameters as a function of the frequency
band information.

         13.   The system of claim 12, wherein the baseband
25   processor comprises:
                  means for receiving the set of baseband
processing parameters from the baseband processor
control unit, wherein the baseband processor extracts

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the digital information from the baseband signal using the received set of baseband processing parameters.

14.   The system of claim 13, wherein the selected set of baseband processing parameters includes channel tracking parameters.

15.   The system of claim 13, wherein the selected set of baseband processing parameters includes automatic frequency control parameters.

16.   A method for processing a baseband communication signal comprising the steps of:
        generating a baseband signal from a radio frequency signal;
        selecting a set of processing parameters based on a frequency band corresponding to the radio frequency signal; and
        adaptively processing the baseband signal based on the selected set of processing parameters.

17.   The method of claim 16, wherein the selected set of processing parameters includes channel tracking parameters.

18.   The method of claim 17, wherein the channel tracking parameters includes a channel tracking step size.

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19.   The method of claim 16, wherein the selected set of processing parameters includes automatic frequency control parameters.

5   20.   The method of claim 19, wherein the set of automatic frequency control parameters includes loop filter coefficients.

21.   A method for receiving a radio communication signal and processing a corresponding baseband signal, the method comprising the steps of:

        receiving the radio communication signal;

        converting the radio communication signal to the corresponding baseband signal;

15   generating a control signal based on a frequency band corresponding to the radio communication signal; and

        adaptively processing the baseband signal as a function of the control signal.

20

22.   The method of claim 21, wherein the step of adaptively processing the baseband signal comprises the step of:

        selecting a set of baseband processing
25 parameters based on the control signal.

23.   The method of claim 22, wherein the step of adaptively processing the baseband signal further comprises the step of:

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processing the baseband signal in accordance with the selected set of baseband processing parameters.

24.   The method of claim 23, wherein the selected set of baseband processing parameters includes channel tracking parameters.

25.   The method of claim 23, wherein the selected set of baseband processing parameters includes automatic frequency control parameters.

26.   In a digital communication system, a method of adaptively generating a digital signal from a baseband signal, the method comprising the steps of:
        transmitting a modulated communication signal;
        receiving the modulated communication signal and converting the modulated communication signal into a baseband signal;
        generating a control signal based on a frequency band corresponding to the modulated communication signal; and
        generating a digital signal from the baseband signal as a function of the control signal.

27.   The method of claim 26, further comprising the step of:
        selecting a set of baseband processing parameters based on the control signal.

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28.   The method of claim 27, wherein the step of generating a digital signal comprises the step of:
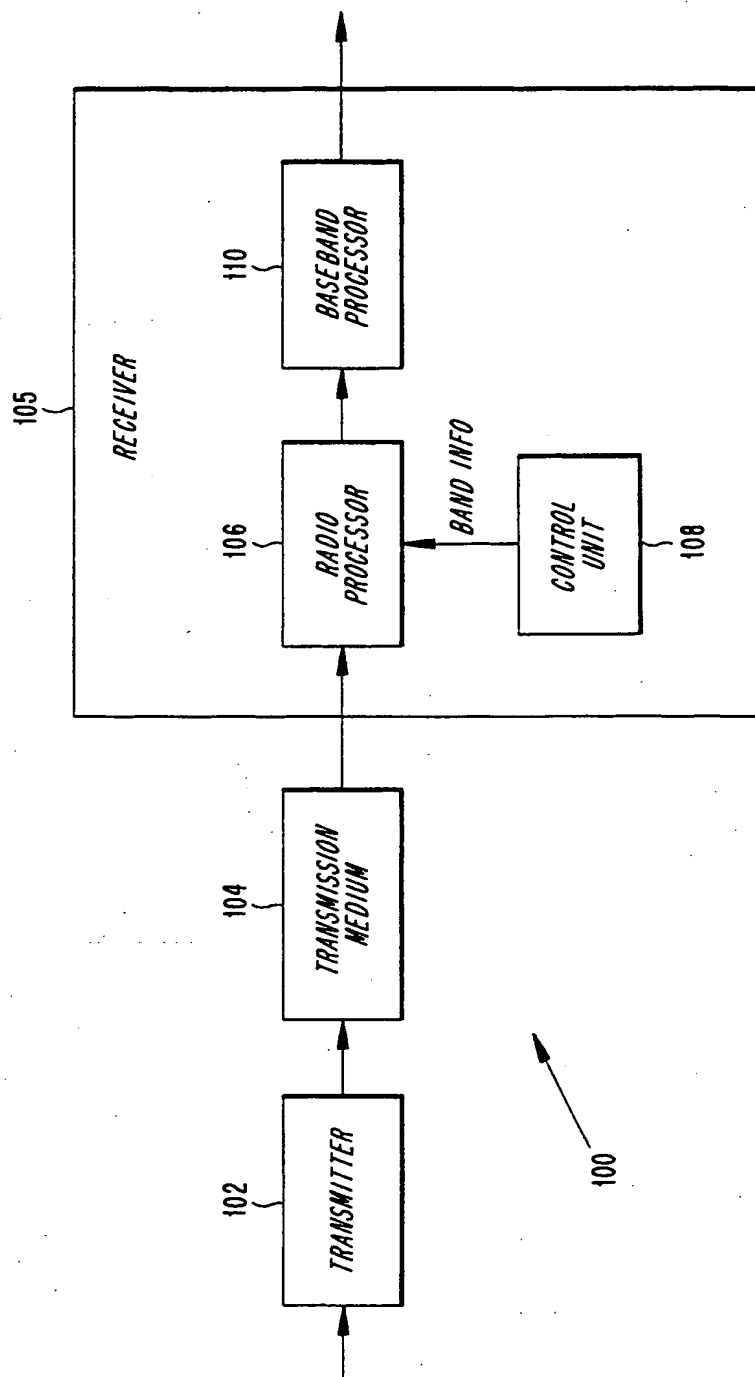generating the digital signal using the selected set of baseband processing parameters.

29.   The method of claim 28, wherein the selected set of baseband processing parameters includes channel tracking parameters.

30.   The method of claim 28, wherein the selected set of baseband processing parameters includes automatic frequency control parameters.
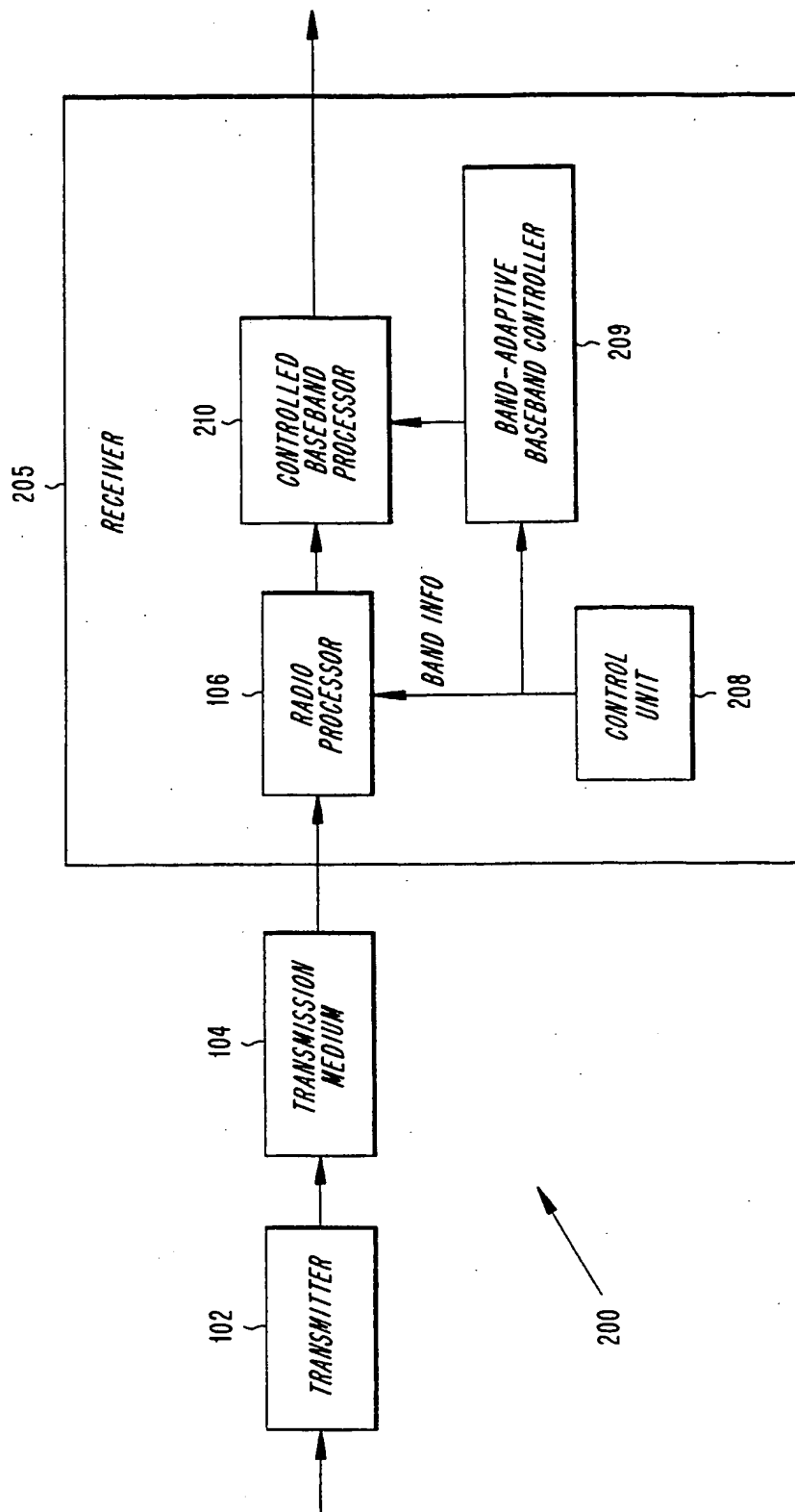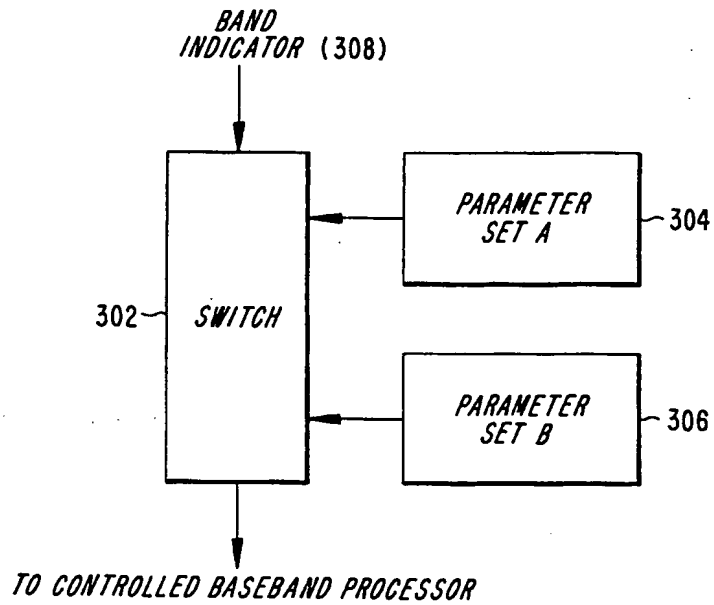
FIG. 1
(PRIOR ART)

FIG. 2

BAND
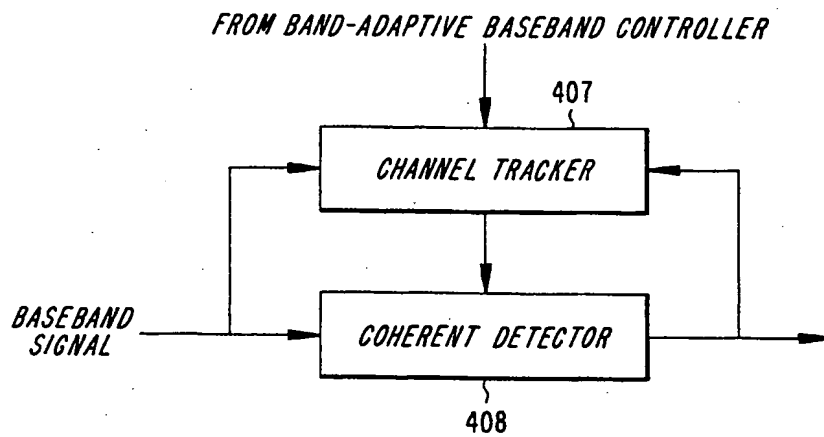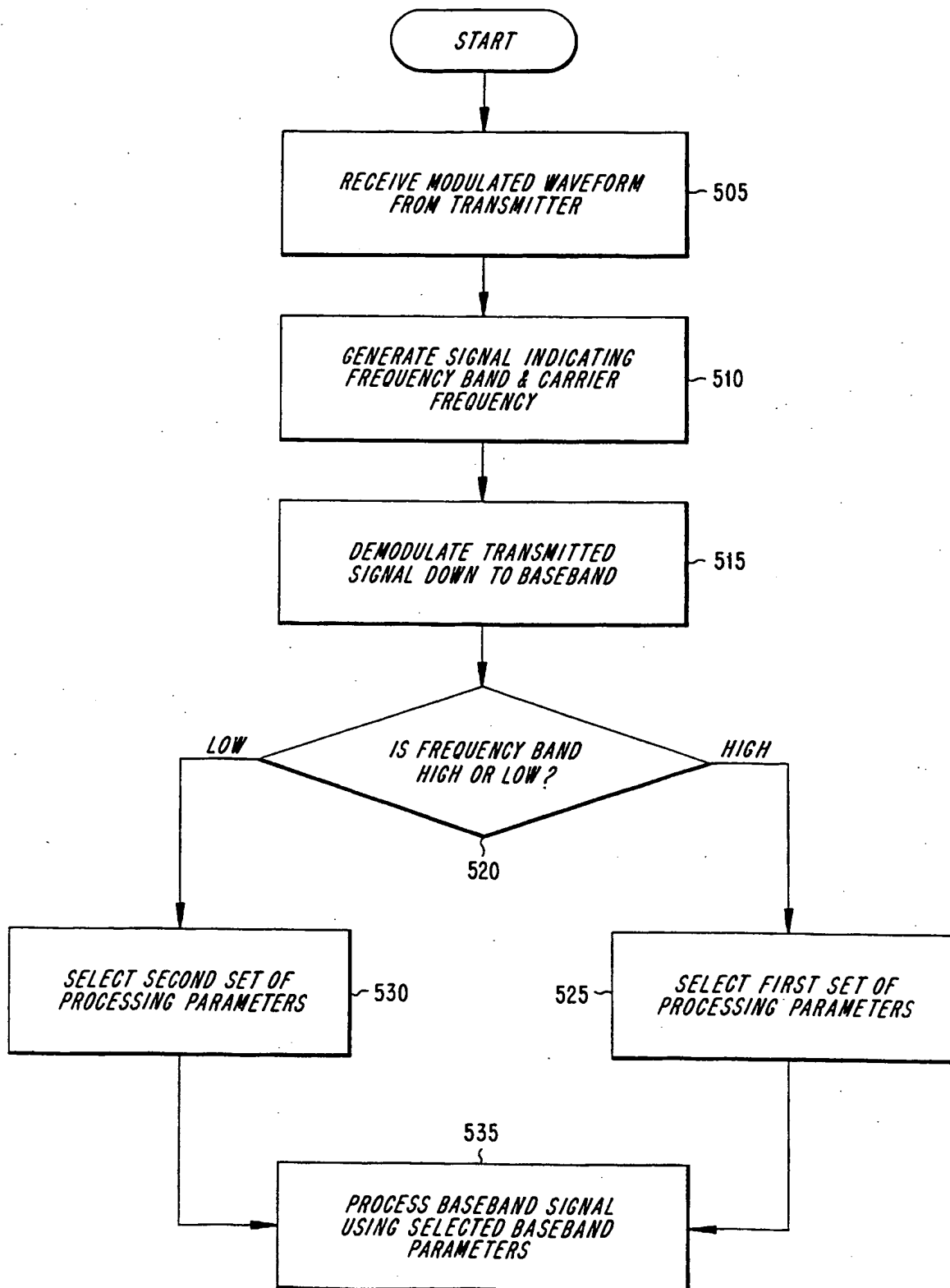INDICATOR (308)

PARAMETER
SET A   — 304

302 — SWITCH

PARAMETER
SET B   — 306

TO CONTROLLED BASEBAND PROCESSOR

FIG. 3

FROM BAND-ADAPTIVE BASEBAND CONTROLLER

407

CHANNEL TRACKER

BASEBAND
SIGNAL

COHERENT DETECTOR

408

FIG. 4

4/4

FIG. 5

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   H04L25/03   H04Q7/32   H03J5/24

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6   H04L   H04Q   H03J   H03H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97 05753 A (QUALCOMM INC) 13 February 1997	1,6-8, 11-13, 16, 21-23, 26-28
Y	see page 1, line 35 - page 14, line 8; figure 1	2,3,9, 14,17, 18,24,29
Y	EP 0 529 585 A (NIPPON ELECTRIC CO) 3 March 1993 see column 2, line 6 - column 3, line 25; figure 4	2,3,9, 14,17, 18,24,29
A	EP 0 446 917 A (NIPPON ELECTRIC CO) 18 September 1991 see column 2, line 1 - line 33; figure 3	1,6,11, 16,21,26

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publicationdate of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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Date of the actual completion of theinternational search	Date of mailing of the International search report
31 August 1998	04/09/1998

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